NOISE MEASUREMENTS DURING TAKE-OFF-CLIMBOUT OPERATIONS OF JET TRANSPORTS

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Presented at the Seventy-Fourth Meeting of the
Acoustical Society of America

Miami Beach, Florida
November 14 through 17, 1967

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ABSTRACT

Data were obtained under closely controlled conditions for both simulated and actual climbouts with the objective of correlating the operation of the aircraft with the measured noise. Two-, three-, and four-engine commercial jet aircraft having turbojet and turbofan engines were included in the program. Good correlation was found between the ground noise measurements and such factors as flight profile, engine thrust, flap setting and aircraft speed. Parametric charts are included to illustrate the significance of the above variables and are shown to be useful for ground noise predictions.

INTRODUCTION

Noise during take-off-climbout operations of jet transport aircraft is an important consideration because of possible adverse reactions in communities near airports (ref. 1). Data have been collected under controlled conditions on several jet transport aircraft (refs. 2, 3, 4, and 5) to determine operating procedures which will minimize noise exposures, and to evaluate a proposed means for performing rapid acoustic evaluations of new aircraft. The objective of this paper is to present some of the results of flight research studies in which the measured noise levels are closely correlated with aircraft operations.

TAKE-OFF-CLIMBOUT NOISE STUDIES

The airplanes used in the test program are shown in figure 1. The airplanes were operated by the FAA, the Boeing Company, Eastern Airlines, and American Airlines (See fig. 1(a), (b), (c), and (d), respectively).

The schematic diagram of figure 2 shows the test set-up for mearuring noise during actual flight operations. Aircraft were operated from a remotely located runway and were flown on various prescribed climbout profiles while being accurately tracked by ground radar. The flight tracks in all cases were made over an array of noise measurement stations deployed along the ground track at distances varying from 11,000 feet to 45,000 feet from the start of roll. Some sample data are presented in figures 3 and 4.

Figure 3 shows perceived noise levels for a four-engine turbojet powered aircraft (See ref. 2). The sketches at the top of the figure illustrate the different climbout profiles employed. The data at the lower left hand side of the figure demonstrate the perceived noise level variations associated with climbout profiles involving various engine thrust levels. Progressively lower perceived noise levels are associated with the slower climb rates which in turn involve lower levels of thrust. The data at the lower right hand side of the figure illustrate the perceived noise levels resulting from a reduction in thrust followed by a subsequent return to take-off thrust. This latter procedure results in relatively higher perceived noise levels following the return to nearly take-off thrust, than if full take-off thrust had been maintained.

The data of figure 4 illustrate the amounts of perceived noise level reductions obtainable by power cutbacks for aircraft having different types of jet power plants. The sketch at the upper left relates to a four-engine turbojet powered aircraft (ref. 2). It can be seen that the reduction in perceived noise level at the time of the power cutback is of the order of 10 PNdB. In the sketch at the lower left, similar data for a four-engine turbofan powered aircraft indicate a smaller noise level reduction. The lesser reduction obtainable for the turbofan is due to the presence of fan noise. The sketches at the lower right relate also to fan powered aircraft (refs. 3, 4, and 5) and it is seen here that the perceived noise level reductions due to power cutback are comparable to those for the turbojet. This results from special design features of these particular turbofans to reduce the fan noise. It is obvious that the amount of noise reduction obtained through power cutback is a function of the type of power plant and its detailed design features and hence no generalizations can be made.

PARAMETRIC FLIGHT STUDIES

In determining the noise exposures at ground level from the climbout operation of a particular aircraft, several factors may be important, as indicated in figure 5. A procedure has been devised which involves controlled flight noise measurements to properly account for all of the factors of the figure and which eliminates the need for repeated take-offs and landings. The nature of this procedure is illustrated in figure 6. The aircraft under radar control, was flown in a level flight altitude to the vicinity of the acoustic range. Just prior to reaching the acoustic range, the engine throttle setttings were adjusted to provide various rates of climb from 750 to 2,400 feet per minute. Data were recorded at each station as the aircraft passed overhead. Tests were repeated for each of the climb rates with initial level flight altitudes of 500, 800, and 1,100 feet. These runs were conducted using fixed flap settings of 0° and 14° which are representative of take-off and climbout conditions. By this means acoustic data were obtained for various aircraft altitudes, at various engine thrust settings, and at the flap settings of interest. The results of these studies are illustrated in figures 7, 8, and 9 for the four-engine turbofan transport airplane.

The maximum sound pressure level values during flyover are plotted as a function of aircraft altitude for three engine thrust conditions in figure 7 for 0° flaps. Also shown in figure 7 is the inverse distance law curve in each case for comparison. The high thrust noise levels are seen to decrease with distance at a rate which closely approximates the inverse distance law. At the lower thrust conditions, however, the sound pressure levels fall off at a rate faster than that of the inverse distance law.

The reason for the differences of figure 7 are suggested in the spectrum plots of figure 8. Sound pressure levels are shown as a function of frequency for a high thrust condition on the left and a low thrust condition on the right for two different aircraft altitudes. The spectra for the high thrust condition contain relatively strong low frequency components whereas the low thrust noise spectra contain relatively strong high frequency components. These differences in the spectral content of the noise and the associated differences in atmospheric attenuation result in different attenuation rates as a function of distance.

The usefulness of parametric data for predicting the noise for a given climbout profile has been evaluated and the results are illustrated in figure 9. This profile involved take-off power with 14° flaps to 1500 feet altitude with a power reduction to produce a climb rate of 500 fpm. Perceived noise level data from three runs involving the take-off-climbout profile shown in the top sketch are plotted as a function of distance from start of roll at the bottom of the figure. For comparison, estimates have been made for the associated perceived noise levels based on the parametric flight studies described above for the appropriate thrust and altitudes of the given profile and these estimates are represented by the two solid curves in the bottom sketch. It can be seen that good correlation exists between the measured perceived noise levels and those estimated from the parametric studies.

The use of the parametric flight concept for the ground noise evaluation of an aircraft in flight may be particularly useful because the need for repeated take-offs and landings is eliminated. It is important to note that aircraft weight is not a significant factor nor is it necessary to make the measurements at an airport. It should be noted, however, that in order to fully exploit this method, the aircraft has to be under positive control at all times and thus the instrument requirements for tracking as well as for acoustic measurements are approximately the same regardless of the method used.

CONCLUDING REMARKS

Power cutback is shown to be beneficial in reducing noise levels under the climbout path, the amount of reduction being a function of the detail design of the airplane. A special flight procedure has been described which produces parametric data sufficient for accurately predicting ground noise levels during climbout.

REFERENCES

1. Anon.: Alleviation of Jet Aircraft Noise Near Airports. A Report of the Jet Aircraft Noise Panel, Office of Science and Technology, Executive Office of the President, March 1966.

2. Copeland, W. Latham; Hilton, David A.; Huckel, Vera; Dibble, Andrew C., Jr.; and Maglieri, Domenic J.: Noise Measurement Evaluations of Various Take-Off-Climbout Profiles of a Four-Engine Turbojet Transport Airplane. NASA TN D-3715, December 1966.

3. Hilton, D. A.; Copeland, W. L.; and Dibble, Andrew C., Jr.: Measurements of Noise Produced by a BAC-111-400 Series Turbofan Transport Airplane During Take-Off-Climbout Operations. LWP No. 211, April 13, 1966.

4. Hilton, D. A.; Dibble, A. C., Jr.; and Copeland, W. L.: Measurements of Noise Produced by a Boeing 727 Turbofan Transport Airplane During Take-Off-Climbout Operations. LWP No. 214, April 20, 1966.

5. Copeland, W. L.; Clark, L. R.; Dibble, A. C., Jr.; and Lawton, B. W.: Further Studies of Noise Produced by a Boeing 727 Turbofan Transport Airplane for Various Take-Off-Climbout Profiles. LWP No. 385, March 1967.

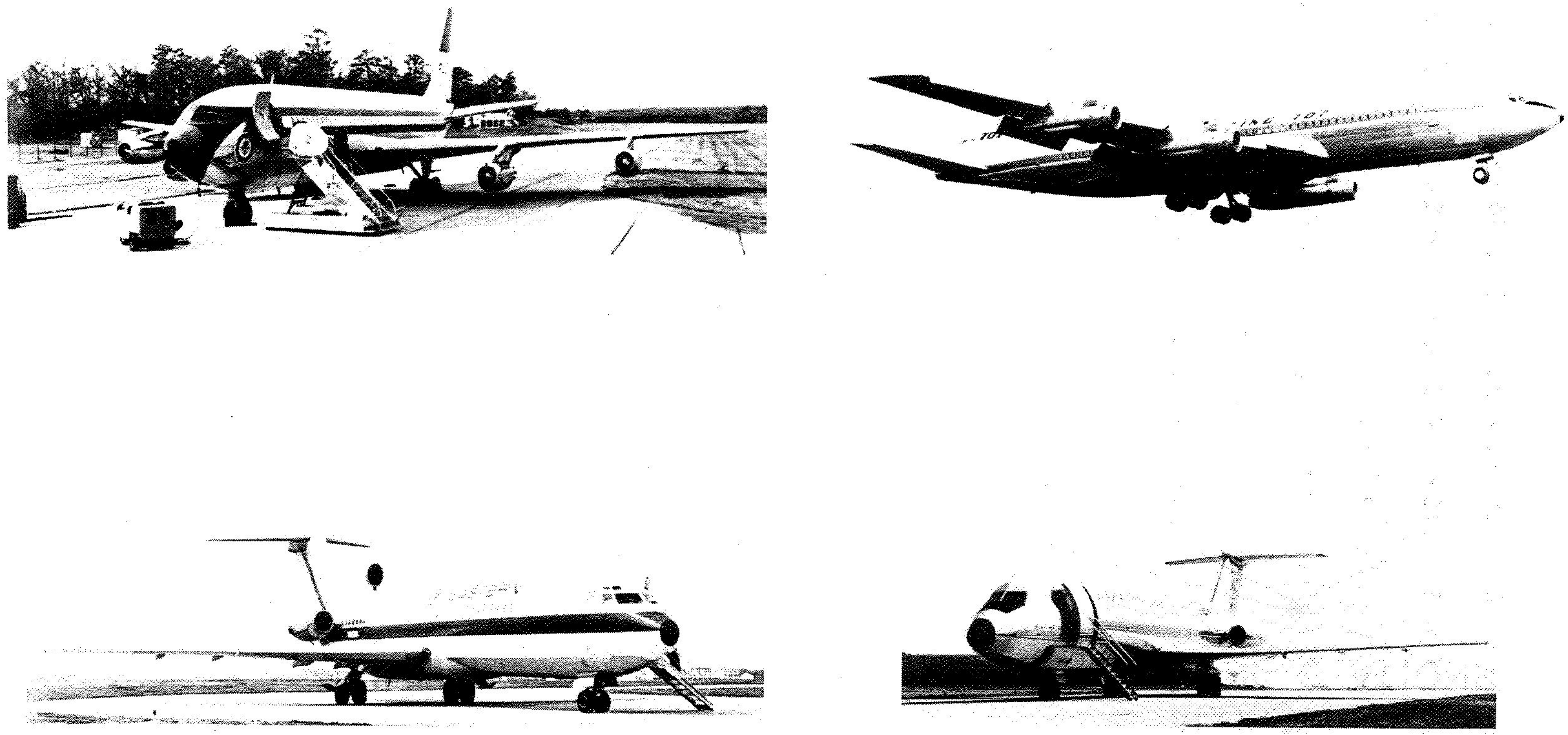

Figure 1.- Photograph of airplanes used in test program.

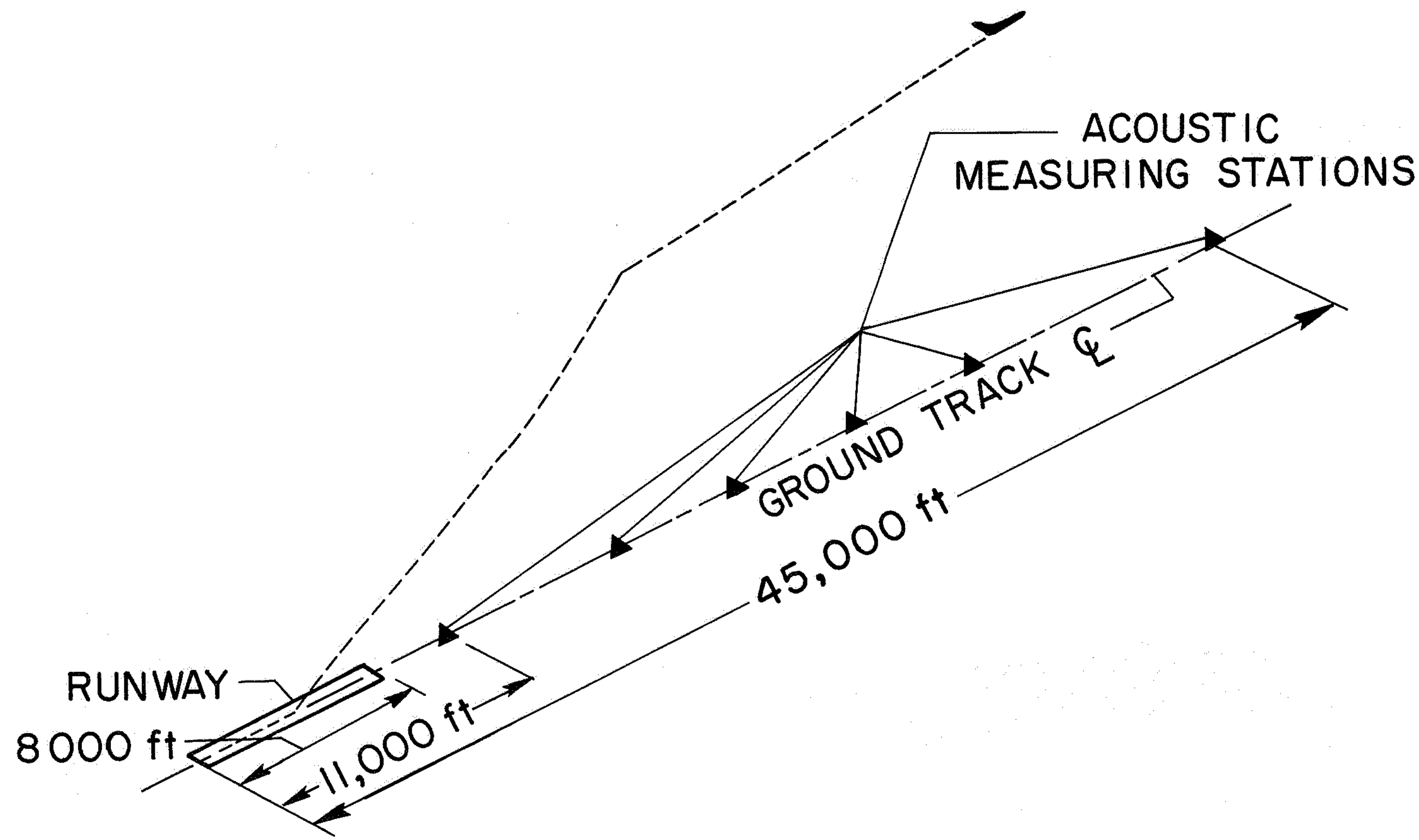

Figure 2.- Schematic diagram showing test setup for measuring noise during takeoff-climbout flight operations.

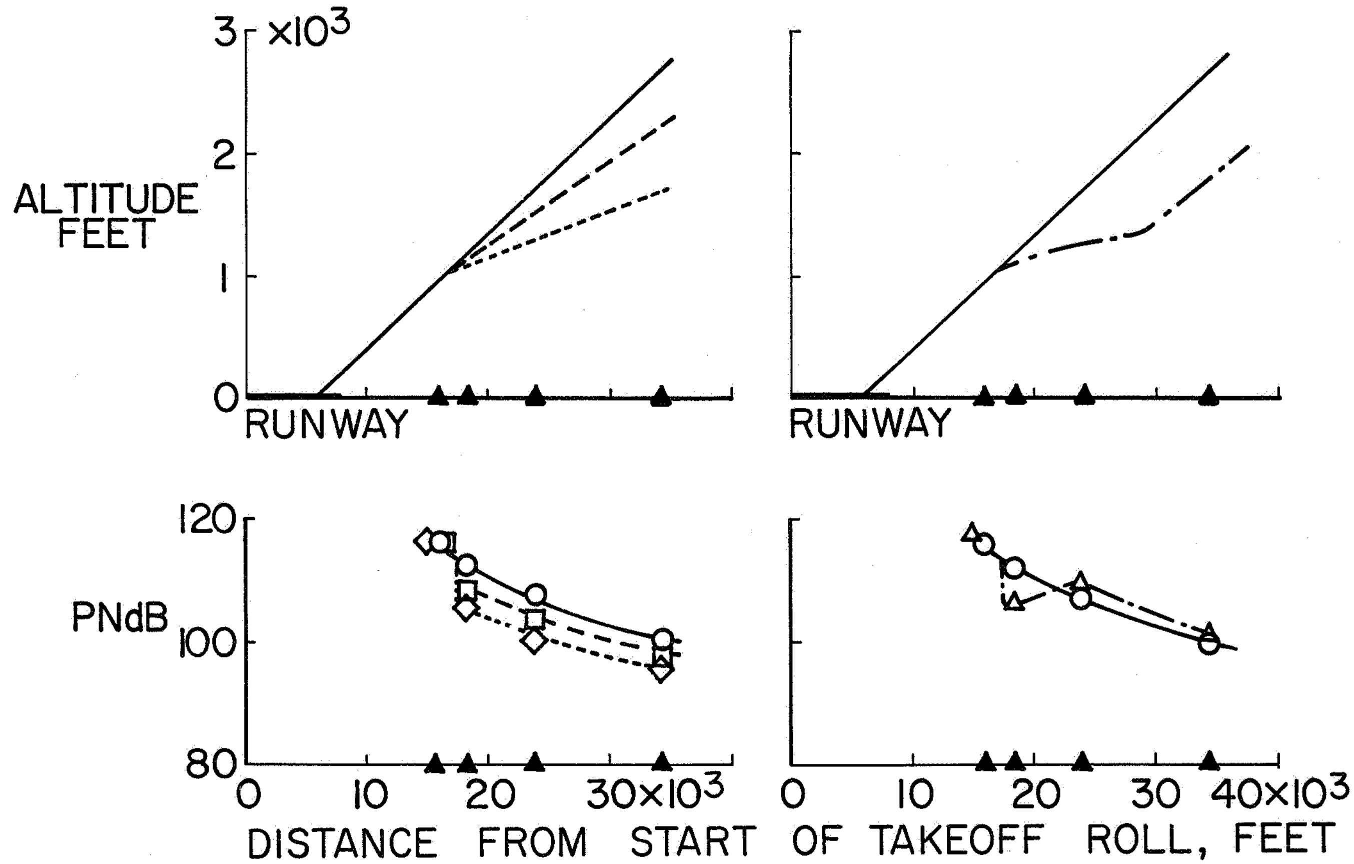

Figure 3.- Effects of engine power schedule on the ground noise levels during climbout of a four-engine turbojet-powered airplane.

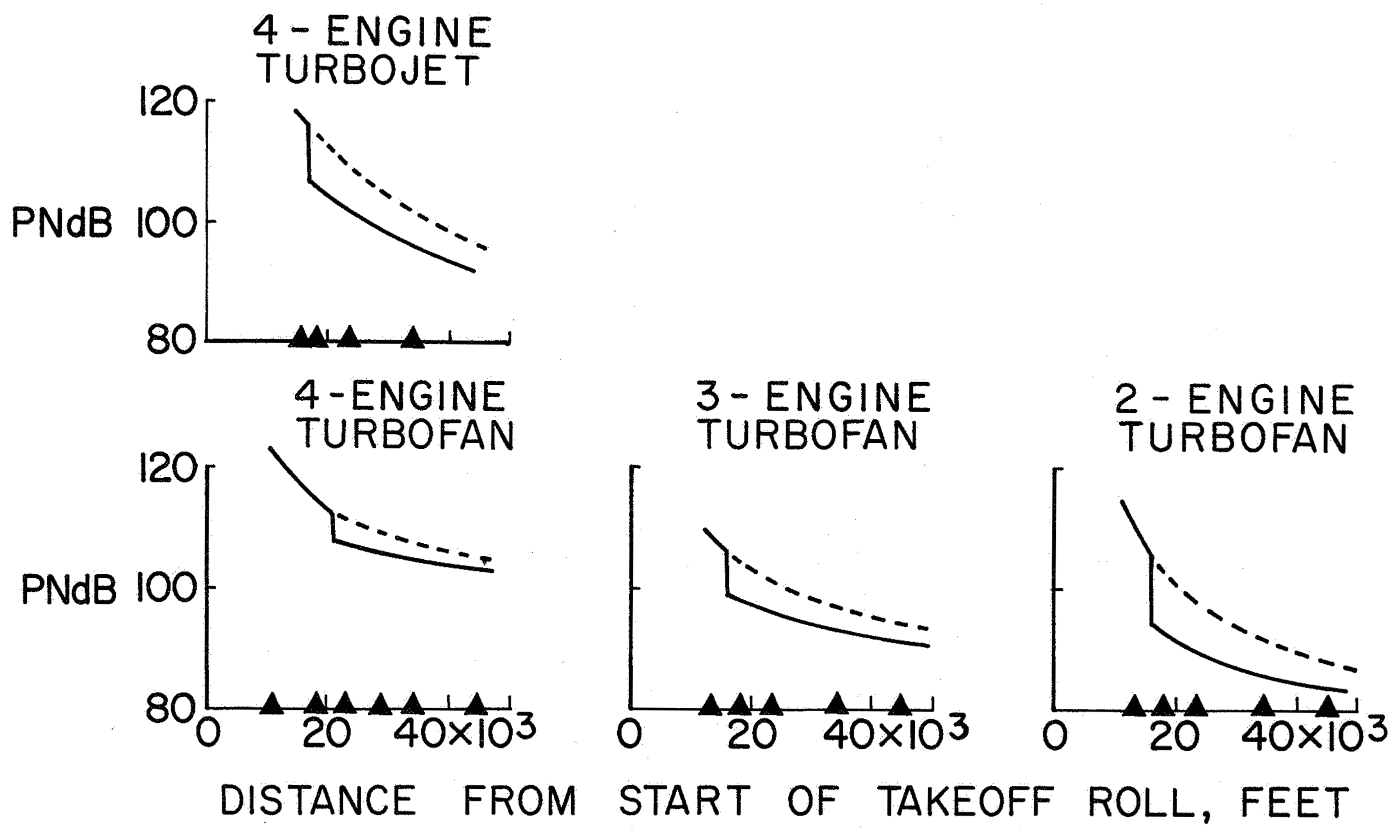

Figure 4.- Noise reduction resulting from power cutback for various type jet engine power plants. (Power reduced to that required for maintaining 500-fpm rate of climb).

- AIRCRAFT SEPARATION DISTANCE
- ENGINE THRUST LEVEL
- FLAP SETTING
- AIRCRAFT SPEED
- AIRCRAFT WEIGHT
- AIRCRAFT CLIMB RATE

Figure 5.- Factors that influence noise prediction on jet-powered transports.

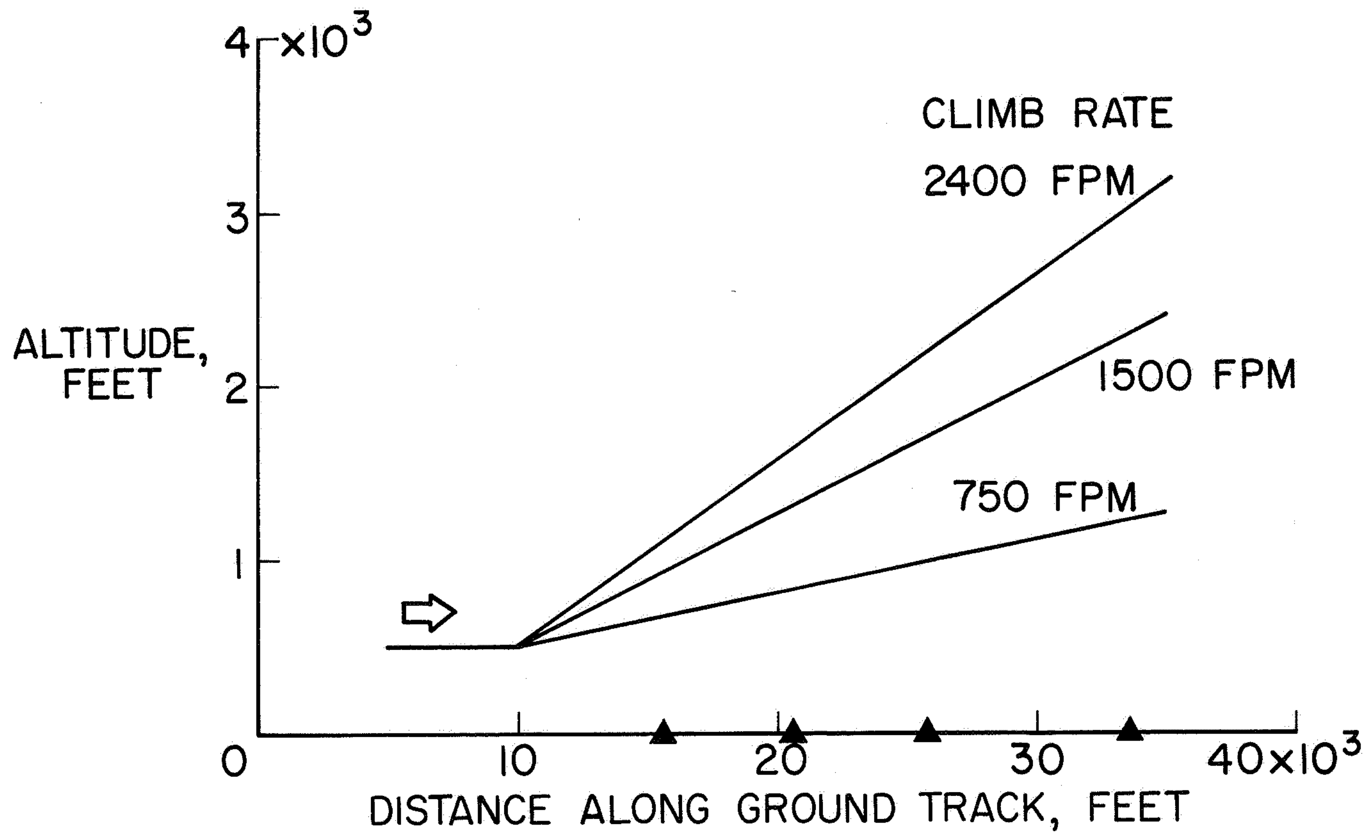

Figure 6.- Sketch showing test setup for measuring noise during parametric flight operations.

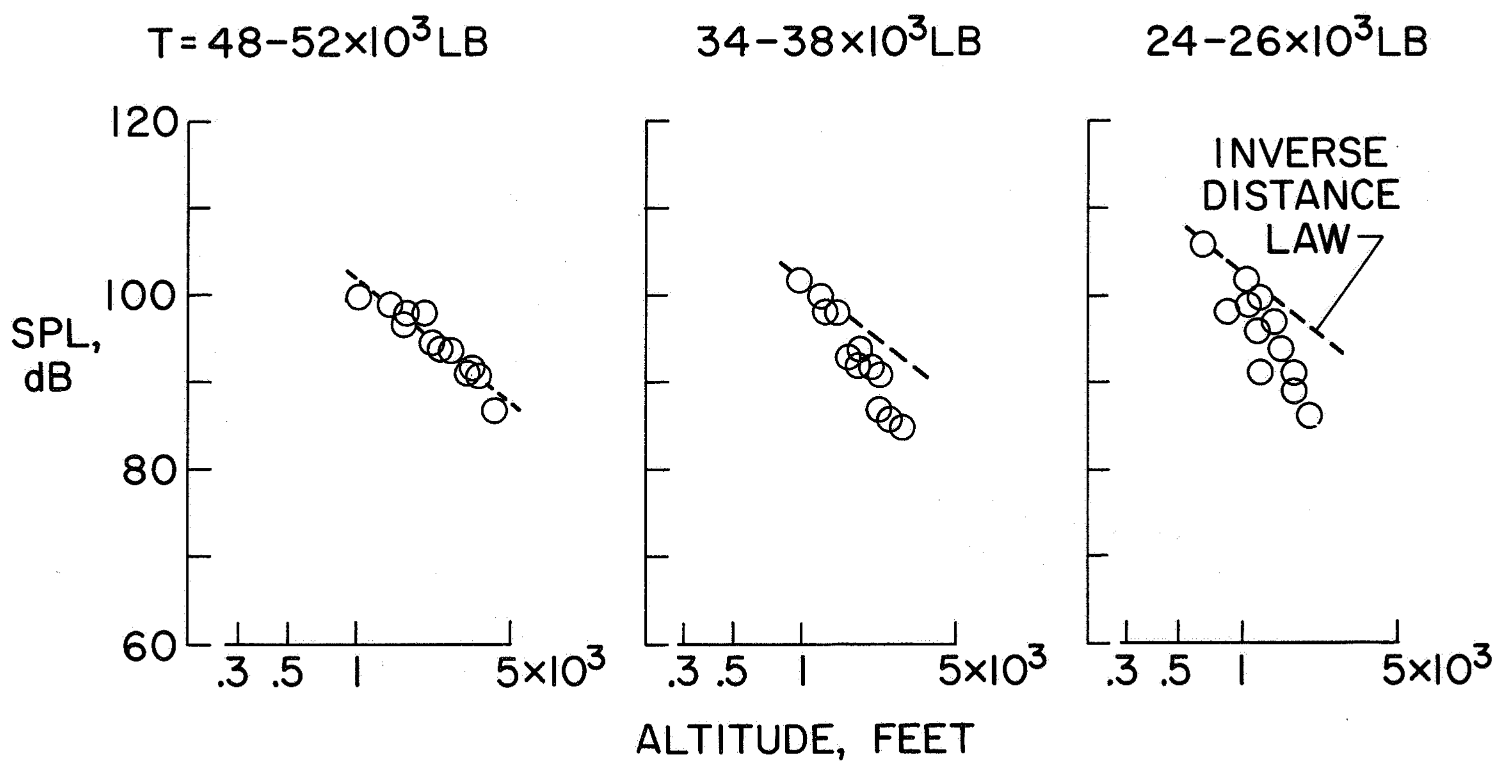

Figure 7.- Maximum sound pressure levels as measured during parametric flight studies using four-engine turbofan-powered airplane.

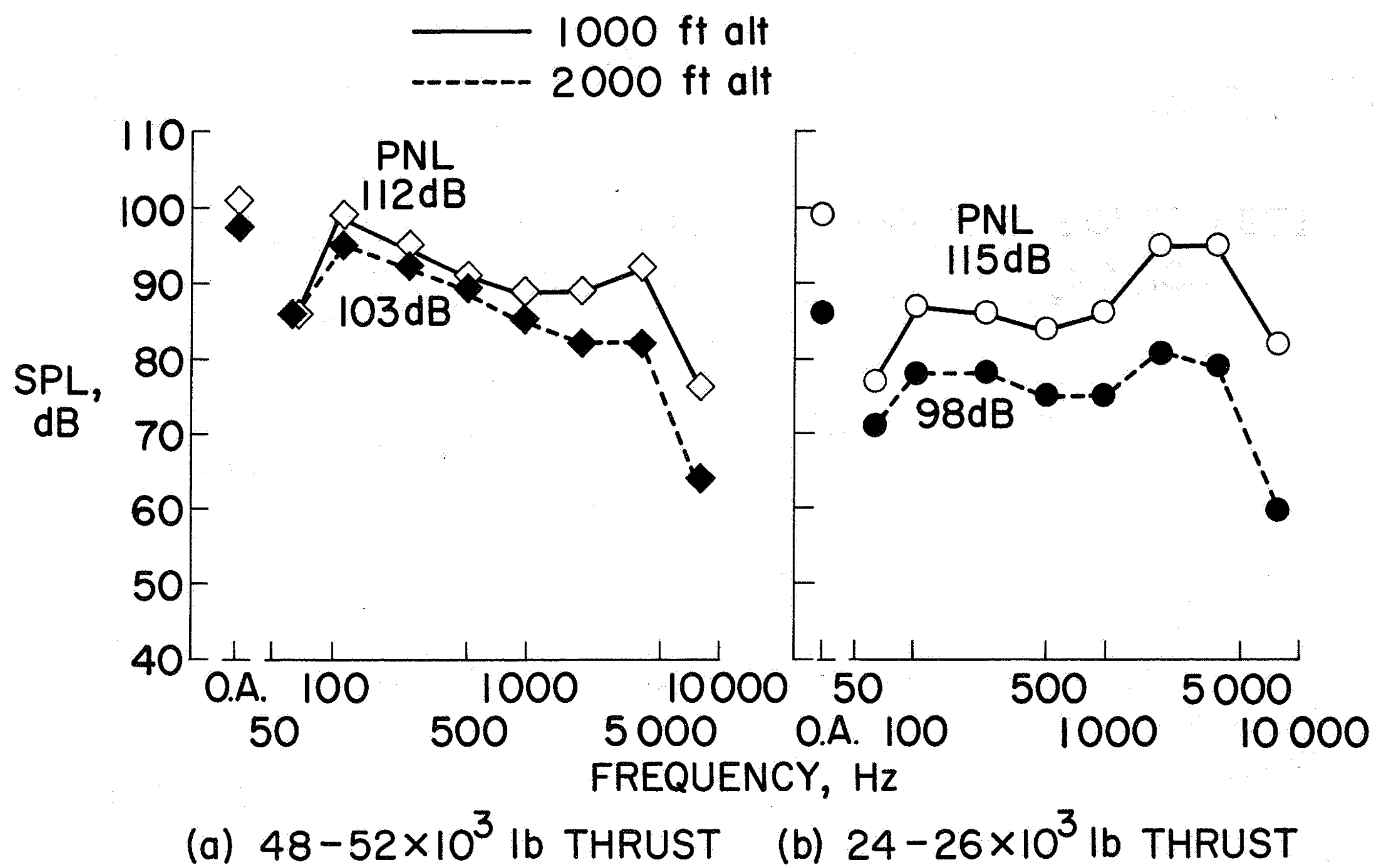

Figure 8.- Comparison of measured noise spectra of four-engine turbofan-powered airplane at two thrust levels and at two altitudes (flaps fixed at 0°).

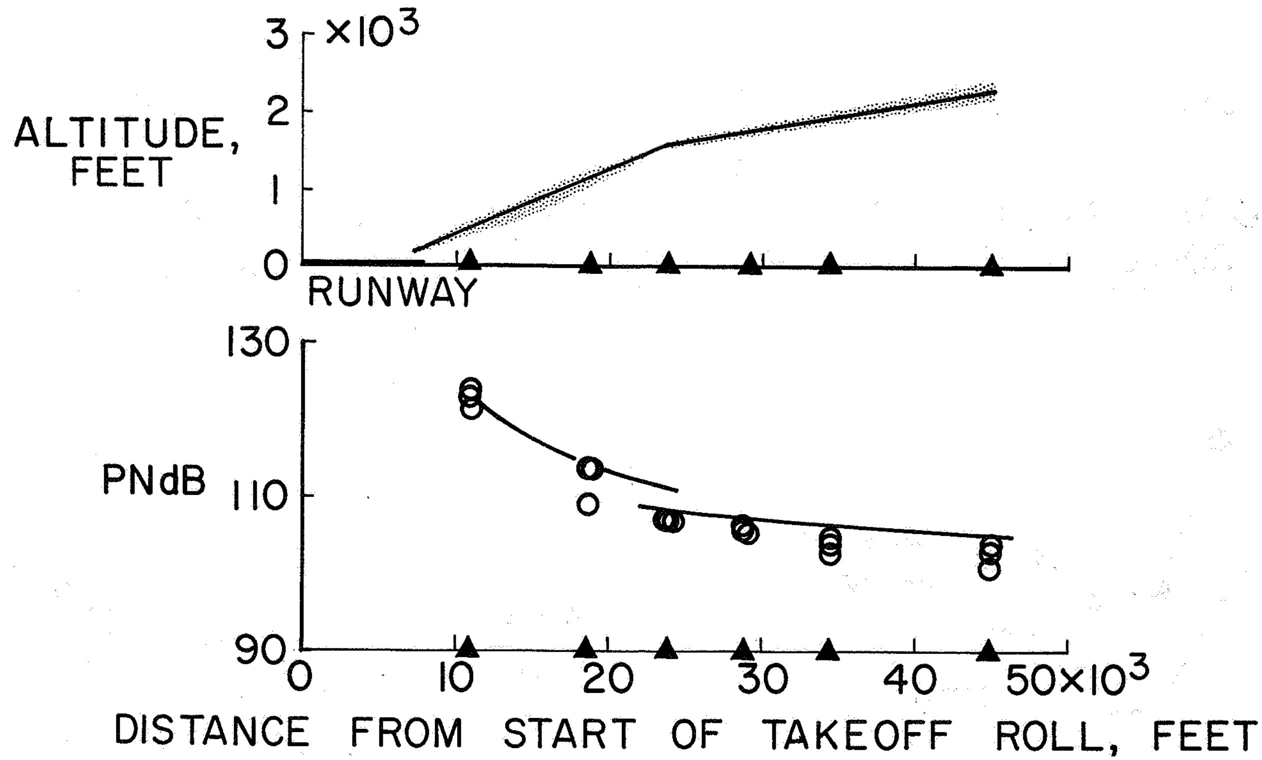

Figure 9.- Comparison of noise levels measured during takeoff-climbout profiles with estimated levels based on noise measurements obtained during parametric flight studies. (Results are for a four-engine turbofan-powered airplane.)

NASA-Langley, 1967